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(54) [Title of the Invention]
Spherical photomask and pattern forming method

[Claims]

What is Claimed is:

1. A spherical photomask which has patterns formed by light-shielding material on a spherical surface of a glass substrate which has at least one spherical surface.

2. A method for forming patterns, comprising the steps of coating a photoresist on a spherical surface of a substrate, closely contacting a patterned surface of a spherical photomask, which has concavity or convexity opposite to and having the same curvature as that of the substrate with said photoresist, exposing said photoresist from the opposite side to the patterned surface of the spherical photomask, and developing the exposed photoresist.

[Detailed Description of the Invention]

[0001]

[Industrial Field of Application]

The present invention relates to photomasks used for photolithography and a method of forming patterns that use the photomasks.

[0002]

[Prior Art]

A conventional technology for providing gratings on a spherical surface is disclosed in Published Unexamined Japanese Patent Application No. Sho 62-30201. The invention is a method for obtaining photoresist patterns by exposing a spherical surface of the spherical substrate coated with a photoresist to interference fringe by the use of an aspherical interference exposing method which uses aspherical waves on an interference exposure wave surface and developing the photoresist. Then, by using a publicly known means (described in the product catalogs of Shimadzu Corporation), the substrate is obliquely etched by ion beams to provide sawtooth gratings on the spherical surface.

[0003]

[Problems to be Solved by the Invention]

However, the above conventional technology requires a large and complicated interference exposing machine as well as extremely strict environmental management for controlling air flow and temperature and eliminating vibration to expose interference patterns.

[0004]

The objective of the invention according to claims 1 and 2 is to provide a method for forming on-off patterns on a spherical surface by using a simple device which ensures mass production without requiring strict environmental management.

[0005]

[Means for Solving the Problems]

The invention according to claim 1 is a spherical photomask which has patterns formed by light-shielding material on a spherical surface of a glass substrate which has at least one spherical surface. The invention according to claim 2 is a method for forming patterns, comprising the steps of coating a photoresist on a spherical surface of a substrate, closely contacting the patterned surface of the spherical photomask, which has concavity and convexity opposite to and having the same curvature as that of the substrate with the photoresist, exposing the photoresist from the opposite side to the patterned surface of the spherical photomask, and developing the exposed photoresist.

[0006]

[Operation of the Invention]

The operation according to claim 1 is that the pattern formed on the spherical surface of the glass substrate shield light at the time of expose. The operation according to claim 2 is at first to form a photoresist having on the spherical surface of the substrate uniform thickness. Next, a photomask which has concavities and convexity opposite to and having the same curvature as that of the spherical surface of the substrate is brought into close contact with the substrate. The patterns on the spherical surface of the photomask are formed by light-shielding material, and light is irradiated from the opposite side to the photomask pattern, therefore, a portion having the light-shielding material the photoresist is not exposed to light, and the only portion having light-shielding material is exposed to light, thereby the patterns are exposed. After the exposure, only the exposed portion (or only the un-exposed portion) can be removed by developing the photoresist. As a result, corresponding on-off patterns with a photoresist are formed on the spherical surface.

[0007]

Hereafter, a method of forming photomasks will be explained with reference to the conceptual diagrams shown in FIGS. 1 through 3. On the spherical surface of a silica glass substrate 1 which has one flat surface and one spherical surface, a chromium layer 2 and a chromium oxide layer 3 are sequentially formed to obtain a mask blank 4 (see FIG. 1). Then, electron beam resist 5 is coated on the surface of the mask blank 4. The electron beam resist 5 is placed on the xyz stage 7 of the electron beam drawing apparatus 6, and desired patterns are exposed to the electron beams 8 (see FIG. 2). After the exposure, electron beam resist 5 of the mask blank 4 is developed and unnecessary electron beam resist 5 is removed (see FIG. 3). The remaining electron beam resist 5 is then used as an etching mask and the chromium oxide layer 3 and the chromium layer 2 are etched. Next, electron beam resist 5 is removed and a spherical photomask is obtained (see FIG. 4).

[0008]

[Embodiment 1]

FIGS 4 and 5 show this embodiment. FIG. 4 is a side view and FIG. 5 is a plan view. Numeral 1 denotes a spherical photomask formed on a silica glass. This spherical photomask 11 has one flat surface 11a and one convex surface 11b having a curvature of 80 mm and the central portion is 15 mm thick. The chromic concentric diffraction grating patterns 11C are formed on the convex surface 11b. The thickness of chromium is 900A. Chromium oxide 11d of 50A is provided on the surface of the diffraction grating patterns 11c to prevent reflection. The pitch of the diffraction grating patterns 11c on the outer circumference is smaller and the smallest pitch is 5 μm.

[0009]

According to this embodiment, it is possible to obtain a mask which can be brought into close contact with a spherically concave surface of the substrate and exposed by using a photomask which has patterns on the convex surface.

[0010]

[Embodiment 2]

FIGS. 6 through 9 are flow sheets showing a forming method according to this embodiment. A glass substrate 12 which has one flat surface 12a and one spherically concave surface 12b having a curvature of 80 mm is heated and sufficiently dehydrated (see FIG. 6), and then a 1.2 μm thick positive photoresist 13 is spin-coated on the spherically convex surface 12b, and pre-baked at a predetermined temperature to remove solvent (see FIG. 7).

[0011]

Next, the glass substrate 12 is placed on a stage 14 and a spherical photomask 11 with concentric diffraction grating patterns according to embodiment 1 is brought into close contact with the spherical surface coated with a photoresist 13 of the glass substrate 12. The photoresist is exposed to ultraviolet rays 16 from the photomask 11 side by an exposure device 15 (see FIG. 8). The photoresist 13 is then exposed in compliance with the patterns of the photomask 11. The exposed photoresist 13 is developed there by obtaining the on-off patterns 17 of the concentric diffraction gratings. After that, the on-off patterns 17 are cured by post baking at a predetermined temperature. Thus, the concave surface diffraction grating can be obtained in which concentric diffraction grating patterns are formed on the spherically concave surface (see FIG. 9).

[0012]

According to this embodiment, it is possible to easily obtain on-off patterns on a concave surface of a substrate by means of contact exposure.

[0013]

The diffraction grating manufactured according to this embodiment can be used as a product. However, it is possible to use it as a diffraction grating original and electrocast and invert the diffraction grating to manufacture a stamper.

[0014]

[Embodiment 3]

FIGS. 10 and 11 show this embodiment. FIG. 10 is a side view and FIG. 11 is a plan view. Numeral 21 denotes a spherical photomask made of silica glass, and the spherical photomask 21 has one flat surface 21a and on concave surface 6b having a curvature of 100 mm and the central portion is 2 mm thick. Equally spaced chromium diffraction grating patterns 21c are provided on the concave surface 21b. The pitch of the diffraction grating patterns 21c is 2 μm.

[0015]

According to this embodiment, it is possible to obtain a mask which can be contact exposed on the spherically convex surface of the substrate by using a photomask which has patterns on the concave surface.

[0016]

[Embodiment 4]

FIGS. 12 through 16 are flow sheets showing a forming method according to this embodiment. A stainless-steel substrate 22 which has one flat surface 22a and one spherically convex surface 22b having a curvature of 100 mm is heated and sufficiently dehydrated, and then a 1.2 μm thick positive photoresist 23 is spin-coated on the spherically convex surface 22b, and pre-baked at a predetermined temperature to remove solvent (see FIG. 12).

[0017]

Next, the stainless-steel substrate 23 is placed on a stage 14 and a spherical photomask 21 having equally spaced diffraction grating patterns according to embodiment 3 is brought into close contact with the spherical surface coated with a photoresist 23 of the stainless-steel substrate 22. The photoresist 23 is exposed to ultraviolet rays 16 from the photomask 21 side by an exposure device 15 (see FIG. 13). The photoresist 23 is then

exposed in compliance with the patterns of the photomask 21. The exposed photoresist 23 is developed to obtain the on-off patterns 24 with equally spaced diffraction gratings (see FIG. 14). After that, the on-off patterns 24 are cured by post baking at a prescribed temperature.

[0018]
Next, by using the on-off patterns 24 of the photoresist 23 as an etching mask, an ion beam etching device etches the stainless-steel substrate 22 by means of argon ion beams 25 (see FIG. 15). The remaining photoresist 23 is removed by oxygen plasma ashing. Thus, the stainless-steel convex surface diffraction grating 26 can be obtained in which equally spaced diffraction grating patterns are formed on the spherically convex surface (see FIG. 16).

[0019]
According to this embodiment, it is possible to easily obtain on-off patterns on a convex surface of a substrate by means of contact exposure.

[0020]
[Effects of the Invention]
The invention according to claims 1 and 2 makes it possible to form on-off patterns on a spherical surface by using a simple method that ensures mass production.

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